# Re-Os ISOTOPIC CONSTRAINTS on the CRYSTALLIZATION HISTORY of IIAB IRON METEORITES.

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The IIAB group represents one of the clearest cases of fractional crystallization of metallic magma during core formation. The Ni-Ir trend in the IIAB group (Fig. 1) has a very steep negative slope which indicates a correspon-dingly high Ir distribution coefficient, and, consequently, high sulfur content in the parental metallic magma [1]. Sta-tistical analyses of the IIAB Ni-Ir trend indicates that the observed scatter of datapoints along the ideal crystalli-zation line is mostly due to analytical uncertainty. This implies that the Ni-Ir distribution pattern in IIAB irons re-flects fractional crystallization, with no significant parallel or subsequent processes. Originally two separate groups were recognized (IIA and IIB) on the basis of their different crystallographic structure and the prominent hiatus in the Ir content. Although, even then it was noted that these two meteorite groups could originate from the same parent body and could represent "segments of a single fractionation se-quence" [2]. Later the Ir content gap was filled in by newly discovered meteorites; and it was accepted that IIA and IIB irons originated from the same parent body and were formed sequentially by fractional crystallization of the same magma pool [3; 4]. Although, the division into A and B subgroups remains; the structural differences and different trace ele-ment behaviour in IIA and IIB meteorites indicate that the crystallization conditions for these subgroups were substan-tially different. Consequently, the focus of the present work was an attempt to resolve the formation time for A and B subgroups.
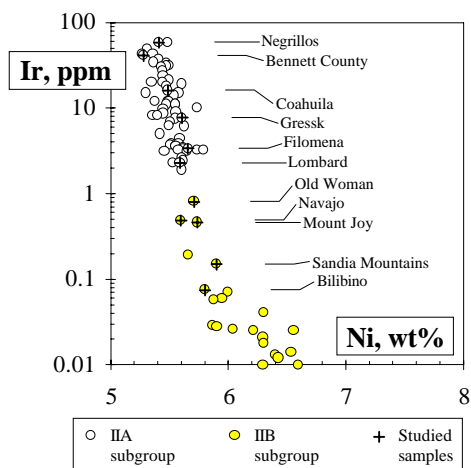
For this study the IIA samples were chosen to cover the whole range of Ir concentrations (Fig. 1) in order to obtaine the maximum range in Re/Os ratio. For the IIB subgroup, samples were confined to Ir contents > 0.05 ppm, to avoid higher uncertainty introduced by the Re blank. One IIB sample is of special interest for the present study - the re-cently discovered Old Woman meteorite. With respect to the chemical composition, this meteorite plots right on the inter-face bet–ween IIA and IIB subgroups [4]. It also shows an intermediate struc–ture - roughly half of this 2700 kg iron is a single hexahedral crystal of kamasite (typical for IIA sub-group), while the other part has the coarsest octahedral structure, very similar to Navajo and Mount Joy - the neigh-bors of Old Woman from IIB subgroup [5]. Specimens from both octahedral and hexahedral parts of Old Woman were analyzed.

Fig. 2 shows the Re-Os experimental results for the IIB meteorites along with previously publisued IIA isochron ([7], age = 4.537 ± 8 Ga, initial $^{187}Os/^{188}Os$ ratio = 0.09550 ± 7, MSWD = 1.15). Low age uncertainty and low MSWD value imply that the whole IIA subgroup crystallized in a narrow time interval not exceeding 16 m.y. Since the IIA subgroup represents the first phase of the IIAB core crystal-lization (Fig. 1), the obtained IIA isochron dates the begin-ning of the core crystallization of the IIAB parent body.
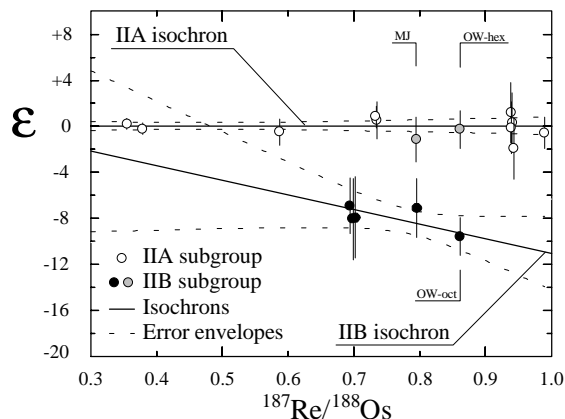


**Figure 2.** Re-Os isotope systematics in IIAB irons. ε is the vertical absolute deviation of an experimental point from the IIA isochron. The IIB samples shown as solid circles were used in isochron calculation. Sample labels: MJ - Mount Joy; OW-hex - Old Woman, hexahedral part; OW-oct - Old Woman, octahedral part.

IIB data show a much lower range in $^{187}Re/^{188}Os$ ratios than the IIA samples. For most of the IIB samples a promi-nent, and concordant negative deviation from the IIA iso-chron was detected (Fig. 2). However, two samples - Old Woman (hex.) and Mount Joy fell out of the rest of IIB set and plot within the error limits of the IIA isochron.

It is interesting to note that only the hexahedral part of the Old Woman meteorite coincides with the IIA irons (which are, in turn, hexahedrites). The octahedral sample of Old Woman plots far below, along with others IIB samples (Fig. 2). The difference in the isotope compositions between the two Old Woman samples is about 9 ε-units, or, in sta-tistical terms, 12σmean, far exceeding possible analytical error. Such a contrast in Re-Os systematics may imply that the two lithologies of Old Woman formed at different times. The other outlying sample, Mount Joy, was by far the most weathered among our IIB set (prominent rusting along ka-



**Figure 1.** Ni-Ir distribution in IIAB irons (data from [6] and references therein).

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macite grain boundaries and around troilite inclusions), so, we attribute its isotopic deviation to a disturbance of the Re-Os system by terrestrial weathering.

The rest of IIB samples - Old Woman (octahedrite), Navajo, Sandia Mountains, and two replicates of Bilibino (Fig. 2, solid circles) - treated together yield an isochron with the age = 4470 ± 79 Ma and initial 187Os/188Os ratio = 0.09565 ± 112 (MSWD = 0.57). The precision of this isochron is much lower than the precision of the IIA isochron - mainly due to the low range in Re/Os ratio in studied IIB set. Also, the precision of individual points of the IIB set is lower because of lower Re and Os abundances, so that the IIB points can not constrain a best-fit line as tightly as IIA samples do. Considering statistical reasons only, our data imply that the IIB irons crystallized somewhere in a 160 m.y. time interval; they can be as old as the IIA group, or they can be substantially younger - up to 4.39 Ga. However, if we take into account the derivation of IIB and IIA irons from the same melt pool, more definite age restrictions can be derived from our data.
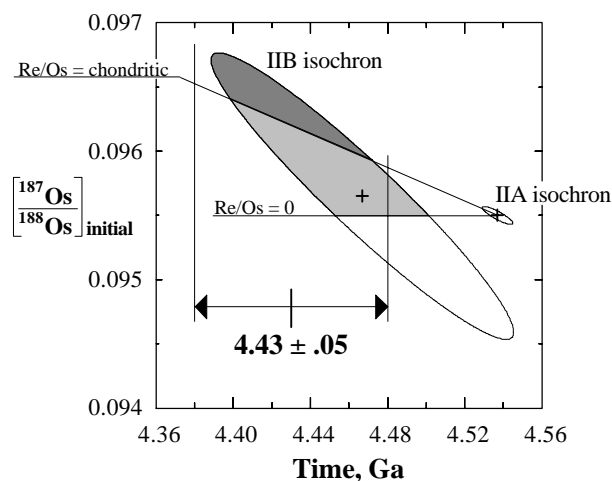


**Figure 3.** Os isotope evolution diagram for the IIA and IIB isochrons. The horisontal line represents the Os evolution in the Re-free environment. The part of the IIB ellips below this line (unshaded) is strictly inconsistent with the common derivation of IIA and IIB irons since it requires the negative Re/Os ratio in the residual melt after the crystallization of the IIA meteorites. Also, it can be shown that the Re/Os ratio in the residual melt after the IIA crystallization was greater than the initial, chondritic, Re/Os ratio. Finally, only the upper segment of the IIB isochron (dark gray) is consistent with crystallization from the same melt pool with the IIA irons.

Fig. 3 illustrates geochemical constraints for the IIB isochron in the form of an evolution diagram. The horizontal line drawn through the IIA isochron represents the evolution in the Re-free reservoir - the Os isotope composition does not change with time due to the [187]Re decay. Everything below this line corresponds to a negative Re/Os ratio, which is impossible. The assumption of derivation from a common magma pool places even more rigid constraint. The chemical modeling of the Re-Os distributions during IIA crystallization shows the Re/Os ratio in the residual magma can not be lower than its initial, chondritic, value. This oblique line

in Fig. 3 was calculated for the chondritic Re/Os ratio, so that only the upper segment of the IIB isochron (dark-gray shading in Fig. 3) is consistent with the derivation from the same magma pool with the IIA irons. The projection of this segment on the time axis finally constrains the age estimate for the IIB meteorites and is both statistically and geochemically consistent. The Re-Os closure age of the studied IIB samples is thus 60 to 160 m.y. younger than the age of IIA irons, or, in the absolute terms:

*IIB crystallization age* = 4.43 ± 0.05 Ga

This result is similar to the isotopic ages of cumulative eucrites. While for the ordinary eucrites quite primitive ages of 4.54 ± .02 Ga were determined independently in different laboratories [**8**], much lower ages were obtained for cumulative eucrites ranging from 4.40 ± .01 Ga (Serra de Mage) to 4.46 ± .03 Ga (Moama and Moore County) [**9**]. Cumulative eucrites, unlike the ordinary eucrites, likely formed at a significant depth. With respect to this study, young ages for Moama, Serra de Mage, and Moore County imply that at least a part of the core of the eucrite parent body was liquid at 4.40 Ga (since the crystallization temperature of Fe,Ni magma is much lower than the crystallization temperature of basaltic melt). So, our present result indicates the IIAB parent body, like eucrite parent body, was geologically active for a substantially long period - at least the first 60 m.y. of its history.

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